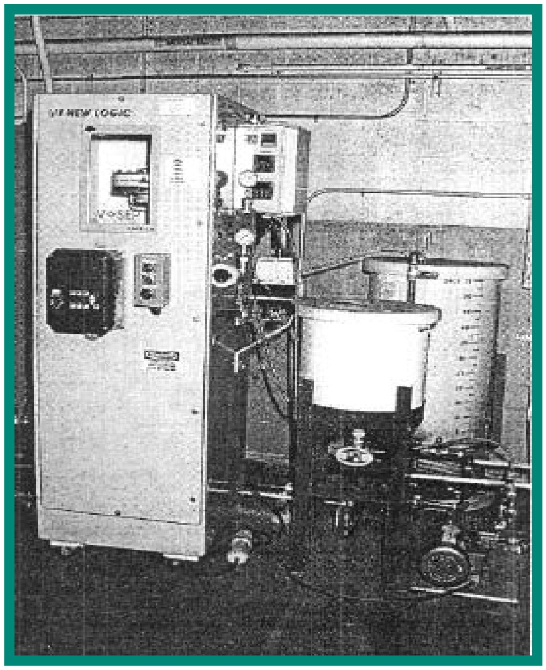
ESTCP
Cost and Performance Report

(PP-9801)



Sodium Hydroxide Recycling System

January 2003

ENVIRONMENTAL SECURITY
TECHNOLOGY CERTIFICATION PROGRAM

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LIST OF ACRONYMS

ARDEC	Armaments Research, Development and Engineering Center
CCAC	Close Combat Armements Center
CRADA	Cooperative Research and Development Agreement
DoD	Department of Defense
DOE	Department of Energy
ECAM	Environmental Cost Analysis Methodology
ESTCP	Environmental Security Technology Certification Program
IWTP	Industrial Waste Treatment Plant
PLC	Programmable Logic Controller
PNNL	Pacific Northwest National Lab
VSEP	Vibratory Shear Enhanced Processing
WVA	Watervliet Arsenal

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Watervliet Arsenal, Operations Directorate and Environmental & Safety Division - Watervliet, NY.

Benet Labs - Watervliet Arsenal - Watervliet, NY.

Corpus Christi Army Depot- Corpus Christi, TX.

Pacific Northwest National Lab - Richland, WA.

MSE Technology Applications Inc. - Butte, MT.

U.S. Army Construction Engineering Research Lab - Champaign, IL.

New Logic International Inc - Emeryville, CA

Technical material contained in this report has been approved for public release.

1.0 EXECUTIVE SUMMARY

The technology demonstrated under this Environmental Security Technology Certification Program (ESTCP) project proved the Vibratory Shear Enhanced Processing (VSEP) system effectively recycled alkaline solutions contaminated with oil and dirt during manufacturing cleaning of material. Benet Labs, Watervliet Arsenal Environmental Office, Pacific Northwest National Lab and New Logic International teamed to successfully demonstrate the use of VSEP to recycle hot alkaline cleaning solutions. High pH alkaline solutions are used at Watervliet Arsenal in bath tanks to clean metal parts prior to further processing and must be replaced every 6 to 8 weeks. The spent solution is disposed of as hazardous waste. The VSEP system offered a new dimension to membrane separation by imparting a shear force at the membrane surface to prevent fouling while maintaining high separation efficiency. Chemical testing verified that contaminates are removed while the active chemical cleaning elements were returned to the tank. This increased the alkaline bath life to 12 months with only small additions of new chemicals and water makeup to compensate for evaporative losses.

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2.0 TECHNOLOGY DESCRIPTION

2.1 TECHNOLOGY DEVELOPMENT AND APPLICATION

New Logic International Inc. of Emeryville, California developed Vibratory Shear Enhanced Processing (VSEP) as an enhanced liquid/solid separation system capable of providing dramatically improved filtration rates over traditional methods. The unit called the Series L/P because it was created to evaluate the correct membrane for the application, L-laboratory mode, and then to scale up to the P-production mode. Each mode requires different set up and operating parameters. The objective of this demonstration was to confirm that the VSEP process as an effective recycling and recovery process for prolonging the bath life of caustic cleaning solutions and reducing the volume of hazardous waste. The testing was accomplished at the active manufacturing finishing area at the Watervliet Arsenal's heat treatment cleaning facility. Data was accumulated and documented to verify the performance and operability of the VSEP system.

2.2 PROCESS DESCRIPTION

Beyond the flow-induced shear of conventional cross flow filtration, VSEP can produce extremely high shear on the surface of the membrane (Reference Figure 1). This is accomplished introducing a torsion vibration of the disk plate in a resonant spring mass system. The membrane, which is attached to this plate, applies an amplitude of 5-10 degrees and the frequency in the range of 54 Hz. The fluid in the membrane remains relatively motionless creating a highly focused shear zone at the surface. Retained solids at the membrane surface has a high effectively removal rate by the shear, allowing for higher pressures and increased permeate rates. Pressure provided by a low flow pump, which circulates fluid to the membrane allows for the process to continue to remove these solids/ rejects. VSEP simply put applies two masses connected to a torsion spring, which when excited at its natural resonant frequency performs the separation. One mass, the membrane pack, is lighter and moves with high amplitude. The other mass, the heavier seismic mass, moves with smaller amplitude proportional to the ratio of the two masses. Using two masses allows the system to resonate without attachment of the device to a rigid surface.

The excitation is created by an AC motor controlled by a variable frequency solid-state speed controller. The motor spins an eccentric weight coupled to the seismic mass. Since the eccentricity of the weight induces a wobble, the seismic mass begins to move the motor speed increases. This energy is transmitted into the torsion spring and begins to move the membrane pack at the top, but at 180 degrees out of phase. As the motor speed approaches the resonant frequency, the amplitude of the moving membrane pack reaches a maximum and the greater motor speed will only decrease the amplitude. VSEP is run below the maximum amplitude to reduce spring stress and ensure an almost infinite spring life.

To allow for free movement, the entire system rides on isolators. Solid piping to the membrane pack assembly is clamped to the torsion spring and is removed at the node (zero amplitude) point. Flexible piping is used at the top of the pack. For safety and sound reduction, the entire assembly is enclosed in a cabinet.

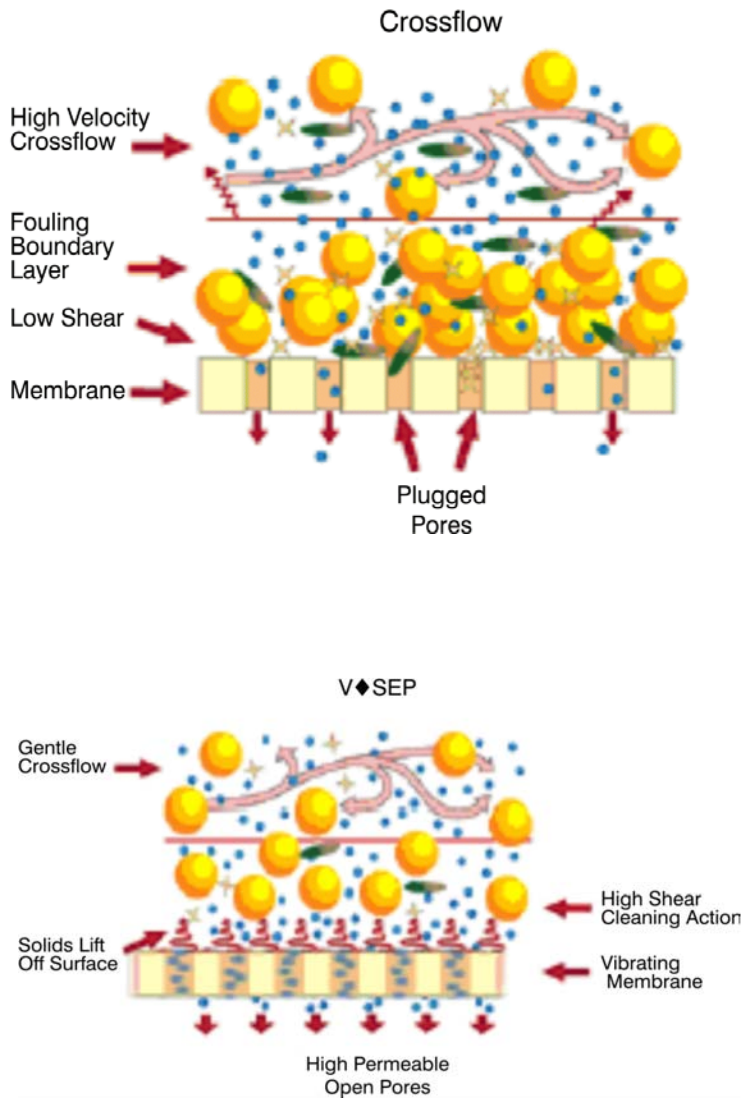

Figure 1. Cross Flow vs. VSEP.

During the operation of the VSEP unit, there are two independent control parameters: shear and pressure. Shear is created by vibrating the membrane pack and the amount of shear is controlled by controlling the amplitude of vibration. Pressure is created by the feed pump and is controlled through the use of valves and a flow regulator. Although shear and pressure are independently adjustable parameters, they must exist together for the VSEP unit to function.

Traditional crossflow membranes plug and foul because the majority of the shear created by the turbulent flow is away from the boundary and cannot efficiently remove retained particles. These inefficient uses of shear accounts for the eventual loss of flux experienced in traditional systems. VSEP's vibration energy focuses shear waves at the membrane surface repelling solids and foulants within the boundary level. This patented method allows for high concentrations while maintaining long term sustained rates up to ten times higher than conventional filtration systems.

2.3 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

VSEP offers the advantage of effectively filtering highly caustic solutions. Today's standard technologies for solution separation, such as reverse osmosis, cannot operate effectively in such harsh environments and traditional crossflow filtration plug and foul because the majority of the shear is created by turbulent flow away from the boundary layer and therefore the retained solids cannot be efficiently removed.

The ability to filter highly caustic solutions will result in significant cost savings verses the costs associated with disposal of hazardous waste and purchase of replacement solutions. Additionally, by maintaining a less contaminated cleaning solution, parts cleaning will be improved.

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3.0 DEMONSTRATION DESIGN

3.1 PERFORMANCE OBJECTIVES

Performance aspects of this demonstration were to determine the ability of the VSEP Filtration System to recover and recycle spent caustic washing solutions. The system was required to meet the following criteria.

- Remove sufficient quantities, estimated as less than 2% of the total volume, of the alkaline solution contaminants in order to recycle the cleaning operation permeate as a caustic solution or a caustic solution base. It is anticipated that some addition of fresh caustic/ surfactant will be required at regular intervals, based on volume. Contaminant levels will vary depending on workload. Bath specifications for the caustic solution contains raw sodium hydroxide at a concentration of between 60 and 120 grams of NaOH per liter. The pH is maintained at 12 or greater.

- Demonstrate the ability to regenerate the washing solution at thru puts up to 3 gallons per minute (gpm).

- Demonstrate safe and economical operation with minimal operator oversight.

3.2 DEMONSTRATION SETUP, COMMENCEMENT AND OPERATION

The prototype system was installed beside the wash tanks in the Minor Plating and Heat Treatment Building at Watervliet Arsenal and will require a three phase, 208 -240 V AC for operation. The system is mobile and easily moved to locations. The space it will occupy will be near the tank and will need no additional work to locate.

The system operated in a continuous mode. Contaminated caustic solutions from the heat treat wash bath caustic tank was pumped through the filtration system with the permeate solution returned to the tank. It required 4 to 5 tank turnovers to clean the tank, this allowed the manufacturing process to continue. The feed, permeate and concentrate solutions were sampled at ports provided by the manufacturer on the unit and analyzed.

This technology has been transferred for installation at Corpus Christi Army Depot (CCAD). They expressed great interest in recycling their alkaline solutions and requested the technology be sent to their site.

The ESTCP demonstration and validation of the VSEP technology was at the Watervliet Arsenal for the production mode and Corpus Christi Army Depot for the laboratory and membrane selection.

During the initial start of the program additional funds were provided by The Industrial Operations Command to modernize the process controls on Line 4 at the Minor Plating Facility at Watervliet Arsenal. This modernization allows for the process flow of material through the line to be modified to maximize flow through the line at the same time reducing discharges form the line. This project has been completed and is not being included in the Cost and Performance Report. Savings however exceeded $30,000 per year based on efficiency throughput and material handling increases.

Contaminants. The system is designed to filter and purify caustic sodium hydroxide solutions for reuse. The system, as tested here, is for recycling spent caustic solutions that have become contaminated during the cleaning processing. Contaminants are oils, grease, metal fragments, grit, and scale that are generated during fabrication and heat treatment.

Process Waste. During the operation of the filtering unit approximately 2% of the total 300 gallons bath will be collected as concentrated oily hazardous waste. This must be shipped off post to be treated.

Factors Affecting Technology Performance. Contaminant type and concentration may affect the filtration efficiency of the system. The amount of contaminant loading on the filter membrane will affect the filtration rate as will physical and chemical degradation of the membrane. Reference appendix G for the membrane selection process.

Reliability. The design of the unit is simple, and the materials used to construct the unit have been proven in the commercial sector. The system uses a new method of vibratory shear to keep the membrane from fouling. This technology is new and endurance testing has not occurred. Mechanical failure of the filtration system is not expected. The use of advanced corrosion-resistant materials allows the unit to function in harsh environments. The system is reliability. The design of the unit is simple, and the materials used to construct the unit have a proven designed for maximum flow rate and contaminant concentration. If these values change, they will most likely influence the system's efficiency and processing time.

System Operation. The system design requires minimal operator assistance and minimal maintenance. Once the system is installed, the only inputs to the system are electricity and spent caustic solution. The system is operated through a graphical man-machine interface. A touch screen provides the operator access to the system in the manual mode. A Programmable Logic Controller (PLC) uses data fed to it from the system to control the process. Minimal instruction is needed to operate the system. Monitoring is required at start-up, shutdown, and at the end of a run and intermittently during operation. Safety controls and alarms are discussed in the system's operations manual. The operation of the system will not interfere with the manufacturing cleaning process. Work can continue.

The system operation features include the following.

- Pressure transducers and controllers to automatically shut the system in the event of system plugging or line failure.

- Flow indicators and controllers to automatically shut the system down in the event of a line failure. Also negated the need for measuring flow manually with a graduated cylinder.

- Temperature indicators to warn the user in the event if an over temperature situation for a given membrane.

- pH indicator to monitor and warn the user in the event of a high pH condition for a given membrane.

- Level switch to automatically shut the system down when the concentrate vessel is full.

- Pre-assembled filter pack such that a membrane pack can be changed out in a manner of minutes instead of hours.

- Transformer to make the system useable in either 440V or 240V wired facilities.

- Cart to make the system transportable if desired.

- Water addition tank to either flush the membrane or provide make-up solution for depleted surfactants, additives, or formula. Membrane flushing during processing will occur at preset conditions.

- Additional valve realignment to route fluid flow as desired.

Variability. The Sodium Hydroxide Filtration System is applicable in any situation where filtration can affect the recycling or purification of a waste. However, the economic variability of the system is dependent upon the waste source volume. This dependency, with respect to spent caustic solutions, will be determined during this demonstration.

Off-the-Shelf Procurement. The prototype system uses a proprietary material manufacturing process developed by New Logic International of Emeryville, California. All other equipment including valves, controls and piping are off-the-shelf items.

Maintenance. Maintenance on the system is discussed in the Operations Manual for the unit.

Scale-up Issues. This system is a full-scale unit designed to process up to three GPM of waste solution. If needed, scale-up can be accomplished by the addition of parallel units or by procuring a larger unit from the manufacturer.

3.3 SAMPLING PROCEDURES

Sampling plan and procedures for this demonstration were provided in the Sodium Hydroxide Demonstration Plan. Performance testing for this demonstration was conducted August 3 to August 11, 1999. Testing of the membranes was conducted in December 1998 and again from February through March 1999.

At the beginning of each test run of the membranes, concentrations were measured at the system inlet or outlet to determine a "baseline." After these concentrations were measured at the system outlet to determine the efficiency of the recycling/recovery process to concentrate and purify the process solution. Flow rate was measured to control the operating conditions. For each batch, the following operational and sampling sequence was followed.

- Prior to equipment start-up, all sampling containers were labeled.

- Samples were collected from the inlet and outlet ports and analyzed for pH, total residue, alkalinity, surfactant and oil & grease. These concentrations represent the initial values.

The VSEP system processes the entire 300 gallons of spent cleaning solution from the bath in each run. The system required 4 to 5 turn over runs to clean the bath. This allowed for the cleaning of parts without interruption. The system operated on the entire volume of 300 gallons. Samples were collected from the outlet port and analyzed for pH, total residue, alkalinity, oil & grease, and surfactant. These samples represent the final values.

The following field quality assurance (QA) samples were also taken and used to evaluate data quality.

Field Duplicate. Consisted of two samples collected consecutively at the same location and placed in separate bottles for separate analysis. These samples were collected at a frequency of one per 20 samples or one per sampling event whichever was more frequent.

Initial Calibration Verification (ICY) and Continuing Verification (CCY). These samples were used to verify the calibration of instruments and to verify the calibration curve for a particular method.

Initial Calibration Blank (ICB) and Continuing Calibration Blank (CCB). These two blanks were used to determine the existence and magnitude of contamination problems caused by instrument memory.

Spikes. Spike sample analysis is designed to provide information about the effect of the samples matrix on the digestion and measurement methodology.

3.4 ANALYTICAL PROCEDURES

Benet Laboratories performed all of the sample analytical testing. Benet Laboratories is located at WVA and is government owned and operated. Benet Laboratories is a division of the Close Combat Armaments Center (CCAC), which in turn, is part of the Department of Army's Armaments Research, Development and Engineering Center (ARDEC). Benet Laboratories provides support to research and development activities conducted at WVA and other DoD facilities.

Methods for sample analysis are shown in Table 1. These methods are all standard EPA methods.

Table 1. Analytical Methods.

Analytic	Matrix	Holding Time	Sample Size & Container	Method
pH	Aqueous	Analyze Immediately	250ml HDPE	Method 424 Standard Method for Examination of Water and Wastewater
Total Solids	Aqueous	Store at 4° C 7 Days	250ml HDPE	Method 208A Standard Method for Examination of Water and Wastewater
Alkalinity	Aqueous	Store at 4° C 14 Days	250ml HDPE	Method 403 Standard Method for Examination of Water and Wastewater
Oil & Grease	Aqueous	Store at 4° C pH<2 H_2SO_4 7 Days	2 liters	Method 502A Standard Method for Examination of Water and Wastewater
Surfactant	Aqueous	Store at 4° C 7 Days	10 micro liters	ASTM E168 Standard Practice for General Techniques of Infrared Quantitative Analysis ASTM D2357 Qualitative Classification by Infrared Absorption

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4.0 PERFORMANCE ASSESSMENT

4.1 PERFORMANCE DATA

A membrane based system for recovery and recycling caustic cleaners has been successfully demonstrated at Watervliet Arsenal and deployed at Corpus Christi Army Depot. Alkaline cleaning processes are typically batch operations and as such, oils, additives and soils collect in the cleaning tank and progressively decrease cleaning efficiency. A typical caustic cleaning solution becomes unusable due to this contamination long before the alkalinity builders, surfactants and the additives are actually consumed.

The application at Watervliet Arsenal was to recycle caustic bath solutions that are used to remove oils and particulate matter from parts used in the manufacture of large weapons. These parts must be cleaned prior to heat treatment and finish coating, thus cleaning is critical to adhesion and the quality of the finish coating, and is directly linked to incidents of rework and scrap.

A Vibratory Shear Enhanced Processing (VSEP) system, a membrane based recycling process, was installed at Watervliet Arsenal with excellent results. The VSEP process makes use of a mechanical arm to vibrate a circular membrane pack in a twisting motion. These motions produce shear waves that propagate sinusoidal from the surface of the membrane such that soils and solids do not have the opportunity to adhere and foul the membrane. They literally bounce off the membrane surface. The membranes for this system are in a pack that would only need replacement on the order of every year to two years. Change out is relatively simple and can be accomplished in approximately 2 hours. The standard VSEP L/P membrane pack has 16.7 sq. ft. of membrane area.

The cleaning of the 300 gallons tank takes about 4 to 5 tank volume turnovers to bring it back to the original virgin state. This is the result of returning the permeate solution back to the original tank so production personnel can continue to use the tank.

During the operation of the unit many samples were taken of the feed, permeate and the concentrated waste solutions. Figure 2 shows, from left to right, a concentrated waste sample, a feed sample and a permeate sample. This picture illustrates that the membranes remove dirt and oil.

4.2 DATA ASSESSMENT

All feed and permeate samples were tested for pH, total solids, alkalinity, oil & grease and surfactants. We encountered great difficulty with the oil & grease analyses using Method 502A of the Standard Method for Examination of Water and Wastewater. We tried very hard to find an alternative test and failing at this we resorted to infrared analyses per ASTM E168 and D2357 to prove that the contaminates were being removed and the good elements of the cleaning solution were remaining. Further investigation and consultation with private industry revealed that this is a common problem, that oil contamination interferes with standard analytical techniques that would quantify what components of an aqueous solution were being retained or passed through a particular membrane.

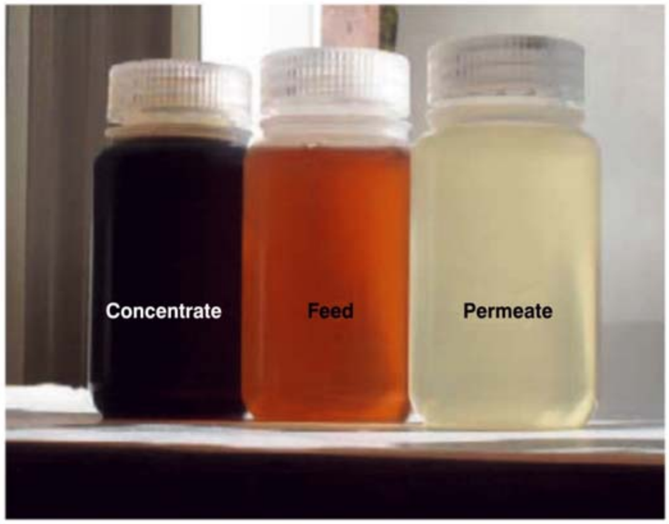

Figure 2. Three Samples Picture.

One company surveyed during the demonstration had determined that IR spectral analyses could be used to identify the occurrence of some additives, but not all. They confirmed “there is no simple analytical method currently available to determine bath makeup solutions after recycling operations.” Their current methodology is to add concentrate in dilute quantities, but they admitted there is no way to accurately determine what the dilution factor might be without obtaining empirical data for each individual bath. Also a problem with adding concentrate is that there’s always the potential for precipitating key elements of the solution. There is currently no method to completely answer the question, “is there a key element missing from the recycled solution?” Attempts to establish a CRADA with this company to develop a testing methodology together for determining caustic bath usability were unsuccessful.

Table 2 contains the data developed from the laboratory analysis.

On the first data sheet the suffix letter denotes samples taken each day, starting of course with A. This data was used to evaluate different membranes performance and then to select the best membrane for our application.

On the second data sheet the prefix letters on the sample # column stand for following: F for a feed sample, P for a permeate sample, and C for a concentrate sample. The suffix letter again denotes samples taken each day.

Figures 3, 4, 5, and 6 show the IR spectral analysis. The first one is a control sample which is virgin material, the second a feed sample, and the third a permeate sample. At the 400 to 1,700 the surfactant/additives range, oil and grease if in the IR at the 950 to 1250 ranges and at the 2300 peak is excess CO_2 which wasn’t purged properly between samples. The CO_2 was meaningless. What were significant are the little peaks in the oil and grease range in the spectra. Some of these were oil; some were oxidized oil suggesting either an oxidized sulfur or nitrate group. The fourth spectrum, the concentrated waste sample, naturally shows the greatest amount of oil and grease in this range. The control sample shows undetectable and the permeate sample shows very little.

Although the analysis indicates what constituents were present and were not present in solution, it was unable to inform the researcher how much.

4.3 TECHNOLOGY COMPARISON

Comparisons with standard cross flow membrane filters showed the VSEP technology to be less likely to plug with his concentrations of debris and oils. The VSEP technology was highly effective for recycling high pH solutions of the type typically found in metal finishing operations. The membranes did not become plugged, nor are they prone to failure as with standard cross flow membranes. The system was simple to set up and with a few minor changes in the operator interface, can be made extremely easy to use. The life of the VSEP membranes far exceeds other standard cross flow filtering systems.

Table 2. Analytical Data.

Sample #	Location	pH	Alkalinity (g/l) to pH 8.3	Total Solids (g/l)	Oil & Grease (g/l)	% Reduction Oil/Grease	Comments
#1 Filter							4000 MNWC UF
120298A	rinse tank	8.75	0.08		0.04		Polyether Sulfone
	1015hr						
120298B	output 1015 hrs	13.13	43.54	95.77	4.35		
							Membrane showed signs of fouling. Light brown residue
121598D	input 1300 hrs	12.98	38.29	89.69	2.66		Excellent Results
121598A	output 1300 hrs	13.03	35.64	86.15	0.10	96.24%	Would require frequent change-out
% Change		0.39%	-6.92%	-3.95%	-96.24%		
121598C	input 1430 hrs	12.98	38.76	xx	3.88		
121598B	output 1430 hrs	13.94	36.97	xx	0.08	97.94%	
% Change		0.46%	-4.62%	#VALUE!	-97.94%		
121698B	input 1145 hrs	12.96	34.04	79.01	1.76		
121698A	output 1145 hours	13.00	31.94	71.09	0.08	95.45%	

Table 2. Analytical Data. (continued)

Sample #	Location	pH	Alkalinity (g/l) to pH 8.3	Total Solids (g/l)	Oil & Grease (g/l)	% Reduction Oil/Grease	Comments
% Change		0.31%	-6.09%	-10.02%	-95.45%		
CONTROL		13.14	33.73	72.93	6.67		
#2 Filter							NTR-7450
021999A	input 1400 hrs	12.69	13.83	35.76	1.10		Sulfonated Polyether Sulfone w/Polysulfone backing
021999B	out 1400 hours	12.75	13.11	31.57	0.11	90.00%	50% NaCI Reject
% Change		0.47%	-5.21%	-11.72%	-90.00%		
022399A	input 1400 hrs	12.75	15.20	37.01	1.02		
022399B	output 1400 hrs	12.76	14.67	31.32	0.16	84.31%	Very Clean/Good flow rates
% Change		0.08%	-3.49%	-15.37%	-84.31%		
022499A	input 1000 hrs	12.74	15.68	38.34	1.33		
022499B	input 1000 hrs	12.74	16.11	38.43	1.44		
022499C	output 1000 hrs	12.71	15.05	32.11	0.31	78.47%	
% Change		-0.24%	-6.58%	-16.45%	-78.47%		
022499D	input 1300 hrs	12.71	15.62	48.03	7.51		
022499E	output 1300 hrs	12.75	16.72	33.69	0.13	98.27	
% Change		0.31%	7.04%	-29.86%	-98.27%		
022499F	input 1600 hrs	12.69	15.20	41.83	2.09		
022499G	output 1600 hrs	12.72	14.06	42.38	0.25	88.04%	
% Change		0.24%	-7.50%	1.31%	-88.04%		
#3 Filter							PES-4H #FQ032693
022599A	input 1000 hrs	12.66	14.76	36.67	0.95		Polyether Sulfone w/Polypropylene backing
022599B	output 1000 hrs	12.70	14.14	30.90	0.07	92.63%	UF-4,000 NMWC
% Change		0.32%	-4.20%	-15.73%	-92.63%		
022599C	input 1300 hrs	12.70	15.68	38.38	0.83		Dark Residue on Surface
022599D	output 1300 hrs	12.72	14.95	31.86	0.73	12.05%	Partially plugged

Table 2. Analytical Data. (continued)

Sample #	Location	pH	Alkalinity (g/l) to pH 8.3	Total Solids (g/l)	Oil & Grease (g/l)	% Reduction Oil/Grease	Comments
% Change		0.16%	-4.66%	-16.99%	-12.05%		
022599E	input 1600 hrs	12.63	14.17	34.40	0.74		Unacceptable
022599F	output 1600 hrs	12.66	13.09	28.65	1.09	-47.30%	
% Change		0.24%	-7.62%	-16.72%	47.30%		
030199A	input 1000 hrs	12.64	14.82	35.88	1.11		
030199B	output 1000 hrs	12.66	13.87	35.41	1.30	-17.12%	
% Change		0.16%	-6.41%	-1.31%	17.12%		
030199E	input 1300 hrs	13.02	15.58	38.01	1.75		
030199D	input 1300 hrs	13.05	15.77	39.83	1.26		
030199C	output 1300 hrs	12.69	14.52	35.07	0.58	53.97%	
% Change		-2.76%	-7.93%	-11.95%	-53.97%		
030199F	input 1600 hrs	13.01	14.82	39.29	1.15		
030199G	output 1600 hrs	13.02	13.68	44.34	0.72	37.39%	
% Change		0.08%	-7.69%	12.85%	-37.39%		
#4 Filter							0.1 micro Teflon w/Typar backing
030299B	output 0845 hrs	13.00	14.25	45.82	0.60		Permeate and Inflow indistinguishable
							Unacceptable
#5 Filter							N30F #FQ02233-4
030299A	input 1230 hrs	13.02	15.20	48.00	0.99		Polysulfone w/polysulfone backing
030299C	output 1230 hrs	13.09	13.11	44.63	1.17	-18.18%	Only 50-ml/min flow rate
% Change		0.54%	-13.75%	-7.02%	18.18%		
030299D	input 1100 hrs	13.02	14.63	43.10	1.11		Very clean surface
030299E	output 1100 hrs	13.07	13.68	37.95	2.10	-89.19%	Unacceptable. Poor flow rate

Table 2. Analytical Data. (continued)

Sample #	Location	pH	Alkalinity (g/l) to pH 8.3	Total Solids (g/l)	Oil & Grease (g/l)	% Reduction Oil/Grease	Comments
% Change		0.38%	-6.49%	-11.95%	89.19%		
#6 Filter							NTR 7410
030399D	input 1600 hrs	12.99	14.63	37.80	0.96		Sulfonated Polyether Sulfone w/Polysulfone backing
030399A	output 1600 hrs	13.04	13.87	38.25	0.08	91.67%	10% NaCI Reject
% Change		0.38%	-5.19%	1.19%	-91.67%		
030399C	input 1300 hrs	12.99	14.63	36.80	1.15		Medium heavy caking on membrane
030399B	output 1300 hrs	13.03	14.06	41.45	0.15	86.96%	Would require frequent changeout
% Change		0.31%	-3.90%	12.64%	-86.96%		
030399F	input 1100 hrs	12.99	14.44	36.41	1.02		
030399E	output 1100 hrs	13.03	13.49	34.41	0.11	89.22%	
% Change		0.31%	-6.58%	-5.49%	-89.22%		
CONTROL		13.12	33.10				
030499B	input 1600 hrs	12.97	14.82	36.55	0.72		
030499A	output 1600 hrs	13.01	13.87	30.29	0.18	75.00%	
% Change		0.31%	-6.41%	-17.13%	-75.00%		
030499D	input 1300 hrs	12.98	14.82	36.20	0.83		
030499C	output 1300 hrs	13.02	13.87	30.24	0.20	75.90%	
% Change		0.31%	-6.41%	-16.46%	-75.90%		
030499F	input 1000 hrs	12.98	14.63	35.79	1.02		
030499E	output 1000 hrs	13.01	13.87	30.35	0.19	81.37%	
% Change		0.23%	-5.19%	-15.20%	-81.37%		
CONTROL			33.44	85.69			

xx sample size for these first samples was too small (250 ml), future samples were doubled in size.

* denotes that the oil and grease results contained both oil and dried residue that made the results higher than it should have been.

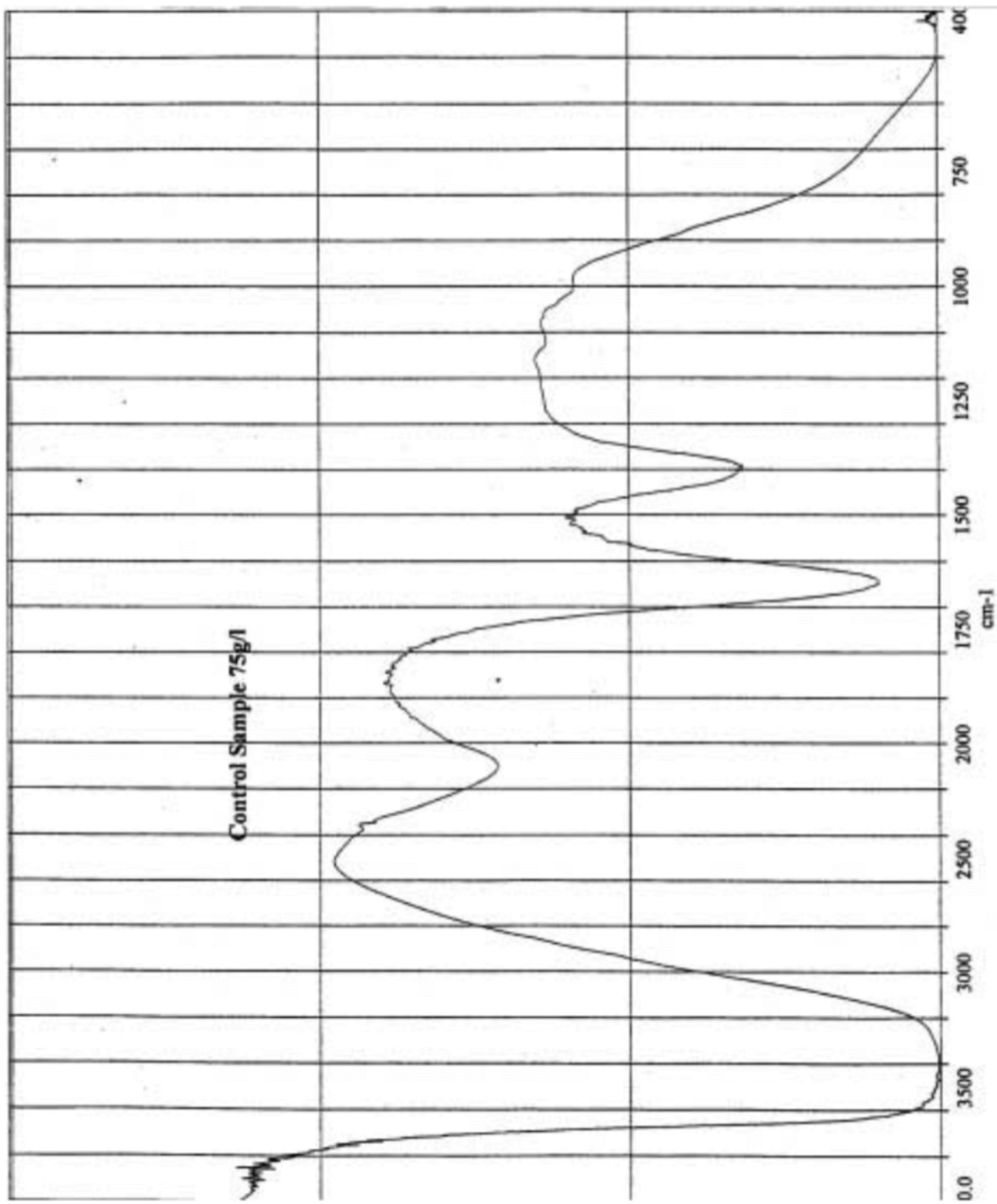

Figure 3. IR Spectra-Control Sample.

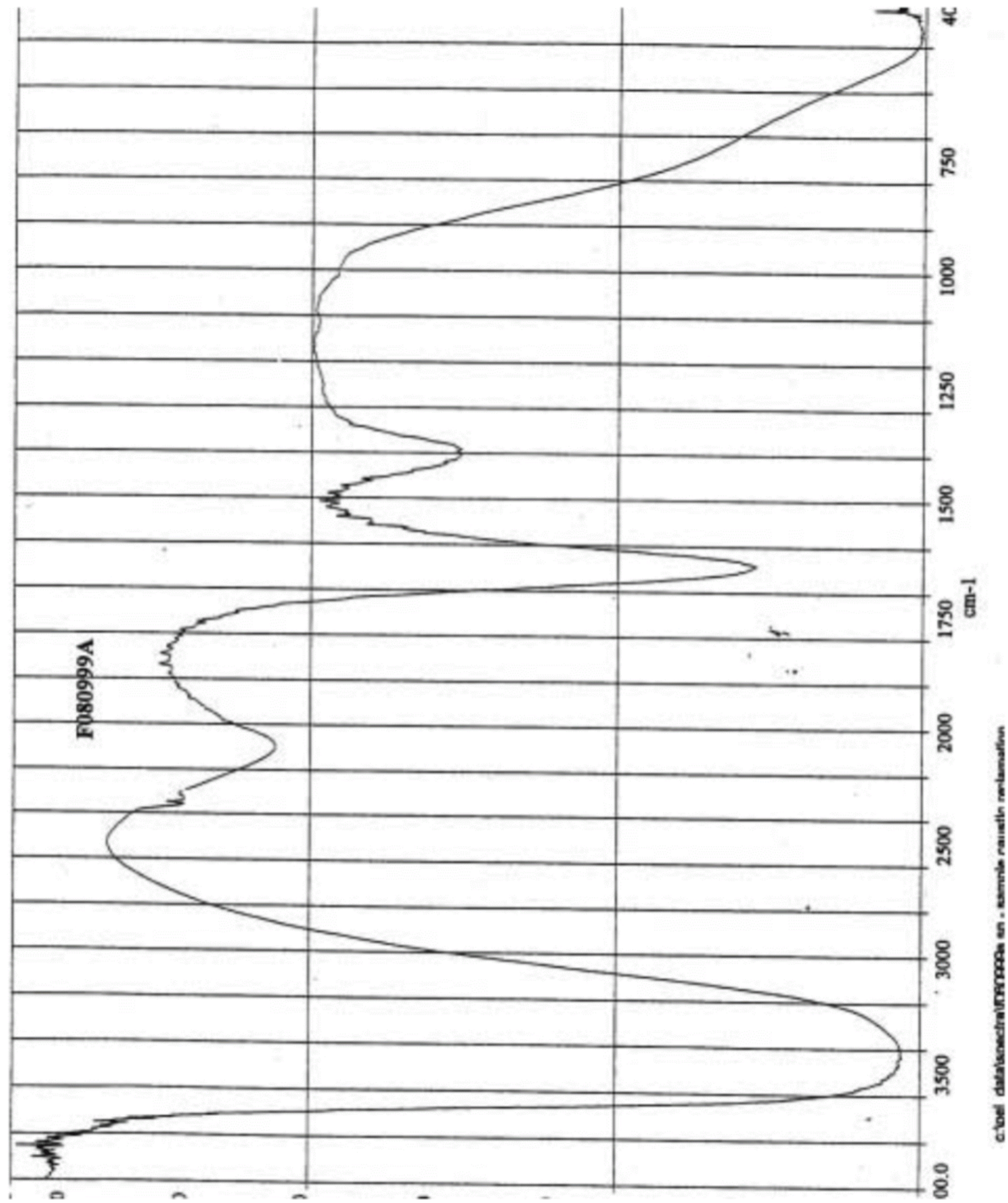

Figure 4. IR Spectra-Feed Sample.

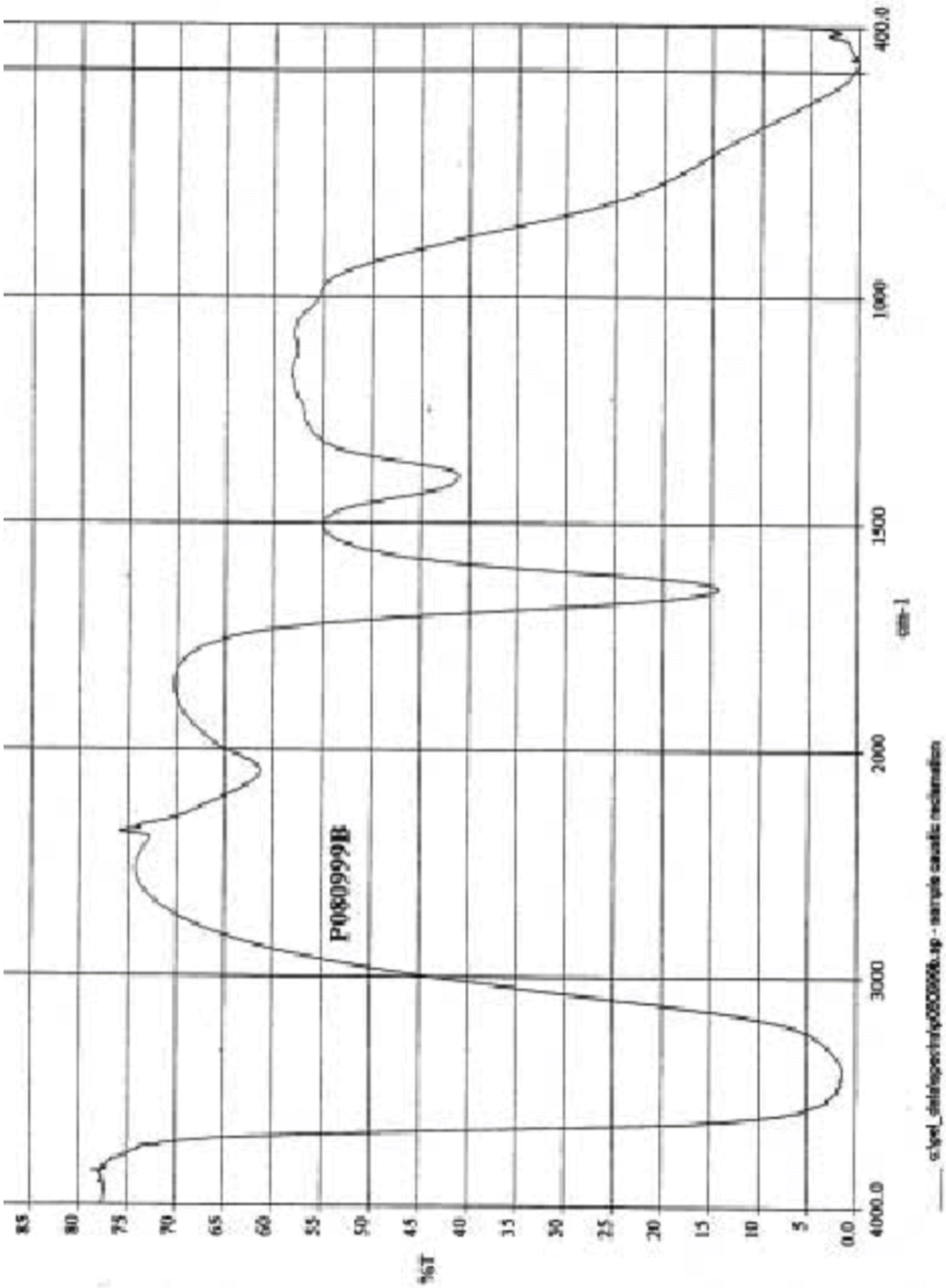

Figure 5. IR Spectra-Permeate Sample.

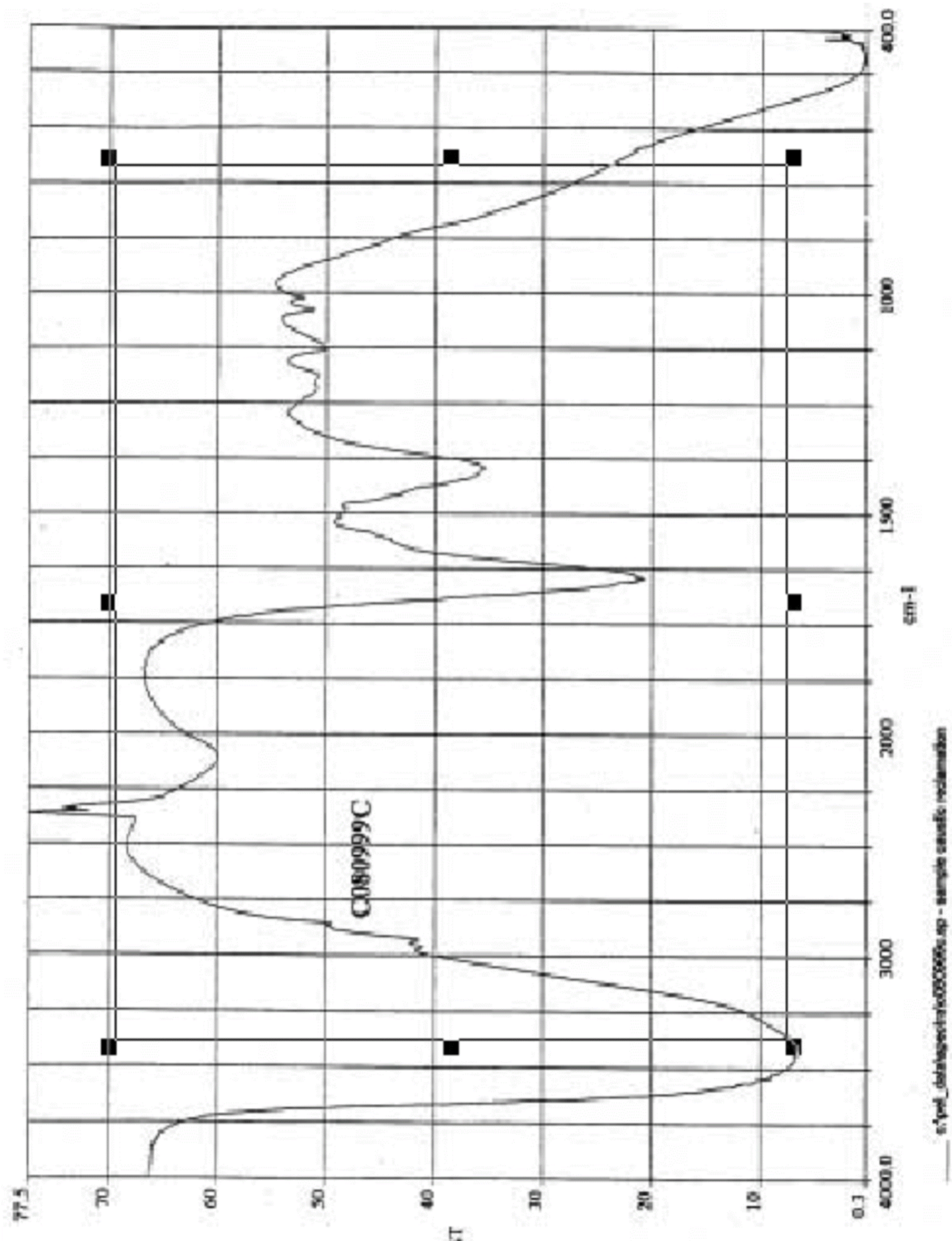

Figure 6. IR Spectra-Concentrate Sample.

5.0 COST ASSESSMENT

5.1 COST PERFORMANCE

The VSEP technology was evaluated using the Environmental Cost Analysis Methodology (ECAM). This document is not enclosed but can be view as a separate document.

A comparison was made between the purchase and installation of a VSEP unit to recycle the caustic solution (Scenario 1) and the disposal of all caustic solution as hazardous waste (Base Scenario).

The VSEP unit from New Logic International Corp is mobile and can easily be moved from site to site. There are no site requirements except electrical power.

	Scenario 1	**Base Scenario**
	VSEP	**All Hazardous Waste**
Initial Investment Cost		
Capital Equipment	$72,000	$0
Annual Operating Cost		
Direct Material	$0	$3,450
Labor	$120,000	$120,780
Utilities	$14,237	$14,146
Waste Management (Labor & Material)	$0	$14,925
Regulatory Compliance	$0	$2,594
Training & Instruction	$1,694	$0
Medical Exams - Lost Labor	$480	$528
Medical Exams	$200	$220
Direct Material - membrane pack	$5,000	$0
Demobilization	$0	$0

5.2 COST COMPARISON TO CONVENTIONAL AND OTHER TECHNOLOGY

A total economic analysis has been prepared evaluating the new technology of using the VSEP unit to recycle caustic solutions (Alternative Scenario 1) vs. the existing base scenario of totally disposing of the caustic solutions. The discounted payback for going with scenario 1, using the membrane system, is 5.34 years.

This P2/Finance, Pollution Prevention Financial Analysis, and Cost Evaluation System is a separate document. The project title is Caustic Recycle.

New technology that competes with the Vibratory Shear Enhanced Processing method especially the extended life of the membranes has not been discovered.

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6.0 IMPLEMENTATION ISSUES

6.1 COST OBSERVATIONS

The cost of a VSEP unit from New Logic was approximately $72,000, and the cost of a membrane pack is estimated at $5,000. The learning curve for operation of the system was estimated to be two weeks under the supervision of New Logic personnel. As operators become more familiar with the unit, the time spent monitoring the unit can be reduced to occasional checks. The site preparations require electrical power and floor space near the bath solution.

6.2 PERFORMANCE OBSERVATIONS

Acceptance testing confirmed the ability of New Logic's VSEP unit to recycle caustic wash solutions. However, a problem was encountered with the analytical testing of the solutions to verify this success. The surfactant was checked using IR spectral analysis per ASTM E168 and ASTM D2357. Difficulty with the oil and grease analysis required the use of IR spectral analysis to confirm that good elements of the cleaners were not removed by the process.

Armor Clean Division of Church and Dwight, a company that had been working with membrane separations/recycling of aqueous cleaners for the past 5 years and had extensive expertise in analysis of these solutions, identified shortcomings of the testing. Discussions about developing a CRADA to share information and work on new testing methods did not result in an agreement.

Due to this failure to establish an agreement, a literature search was conducted resulting in the following ASTM specifications.

- G-120 Determination of Soluble Residual Contamination in Material and Components by Soxhlet Material.

- G-121 Preparation of Contaminated Test Coupons for the Evaluation of Cleaning Agents.

- G-122 Evaluating the Effectiveness of Cleaning Agents.

It is believed that some modification will result in easier and more accurate methods thus resulting in better data. Unfortunately lack of time and funding prevented a more thorough investigation of these methods.

6.3 SCALE-UP

The VSEP unit tested can be utilized in a laboratory mode to evaluate membranes for each alkaline solution, and, with minor changes, the same unit could go to a production mode, capable of thru puts up to 3 gallons per minute.

6.4 OTHER SIGNIFICANT OBSERVATIONS

Results indicate the VSEP technology can be effective for recycling high pH solvents and baths of the type typically found in metal finishing operations. The membranes did not become plugged nor were they prone to fail. The system is relatively easy to setup and with a few minor changes in operator interface can be made extremely easy to use. Recommendations were made to New Logic to correct these minor changes in the operation of the VSEP system.

6.5 END USER/ORIGINAL EQUIPMENT MANUFACTURE (OEM) ISSUES

The VSEP unit was shipped to Corpus Christi Army Depot (CCAD) Corpus Christi, Texas for evaluation on recycling three different alkaline solutions. This technology sharing was initiated to show the versatility of the VSEP technology and was so successful that CCAD wants to purchase a unit to utilize full time at their facility.

6.6 APPROACH TO REGULATORY COMPLIANCE AND ACCEPTANCE

The need for every DoD facility and private industry facility to reduce the generation of hazardous waste cannot be emphasized enough. When new technology shows promise in reduction of this waste, it is worth investigating. No new or additional permits are required to have a VSEP unit.

7.0 REFERENCES

1. New Logic International, VSEP Operating and Maintenance Manual.

2. Phelps, Max, Sodium Hydroxide Recycling Membrane Selection, PNNL, November 1999.

3. U.S. Environmental Protection Agency, Preparation Aids for the Development of Category III Quality Assurance Project Plans, EPA/600/8-91/005, Washington, DC, February 1991.

4. U.S. Environmental Protection Agency, Test Methods for Evaluating Solid Waste - Physical/ Chemical Methods, SW-846, US EPA, Washington, DC 1986.

5. U.S. Environmental Protection Agency, Laboratory Data Validation, Functional Guidelines for Evaluating Inorganic Analysis, July 1, 1988.

6. U.S. Environmental Protection Agency, Methods for Chemical Analysis of Water and Wastes, EPA/600-4-79-020, US EPA, Washington, DC, 1983.

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APPENDIX A

POINTS OF CONTACT

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